Planned complex suicide combining pistol head shot and train suicide and Virtopsy examination

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Abstract: This case report focuses on the findings in what appeared to be a planned complex pistol head shot and train suicide. The post mortem computed tomography (PMCT) scan in this instance yielded two interesting skull fragments among the many fragments of a highly fragmented body and head. These two fragments, based on initial resolution, appeared to show findings consistent with a firearm shot to the head. Upon reconstruction of higher resolution data, the necessary discrimination of non-gunshot related semi-circular fragment rims and firearm-related beveling matched the macroscopic aspect of the skull fragments. As a first lesson to be learned, a thorough examination of PMCT data in relatively high degrees of fragmentation may have to inspect all bone edges also for relatively subtle changes, possibly indicative of sharp force trauma or gunshot trauma. To that end, individual bone fragments should be placed on the scanner table carefully and with proper spacing, to expose their edges. Only this allows to capture data that avoids edge overlaps or edge collisions and that allows for optimal checking of the edges of all bone fragments for possible semicircular defects in the PMCT data. A second technical lesson to be learned is that particularly in instances of high fragmentation of at least parts of a body, resolution may have to be at least as good as maximally achievable. To that end, availability of the raw data to reconstruct images with maximal image quality rather than using a trade-off between lesser cost and lesser yield may be a key issue. A third lesson to be learned is that findings in relatively highly fragmented bodies as consequence of an apparent form of injury - fire/thermal, fall from great height, collision with a train - for other forms of trauma - sharp force trauma, firearm injury - may have to interpreted with caution, particularly with regard to what can be ruled out.

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Planned complex suicide combining pistol head shot and train suicide and Virtopsy examination

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ABSTRACT

This case report focuses on the findings in what appeared to be a planned complex pistol head shot and train suicide. The post mortem computed tomography (PMCT) scan in this instance yielded two interesting skull fragments among the many fragments of a highly fragmented body and head. These two fragments, based on initial resolution, appeared to show findings consistent with a firearm shot to the head. Upon reconstruction of higher resolution data, the necessary discrimination of non-gunshot related semi-circular fragment rims and firearm-related beveling matched the macroscopic aspect of the skull fragments. As a first lesson to be learned, a thorough examination of PMCT data in relatively high degrees of fragmentation may have to inspect all bone edges also for relatively subtle changes, possibly indicative of sharp force trauma or gunshot trauma. To that end, individual bone fragments should be placed on the scanner table carefully and with proper spacing, to expose their edges. Only this allows to capture data that avoids edge overlaps or edge collisions and that allows for optimal checking of the edges of all bone fragments for possible semicircular defects in the PMCT data. A second technical lesson to be learned is that particularly in instances of high fragmentation of at least parts of a body, resolution may have to be at least as good as maximally achievable. To that end, availability of the raw data to reconstruct images with maximal image quality rather than using a trade-off between lesser cost and lesser yield may be a key issue. A third lesson to be learned is that findings in relatively highly fragmented bodies as consequence of an apparent form of injury - fire/thermal, fall from great height, collision with a train - for other forms of trauma - sharp force trauma, firearm injury - may have to interpreted with caution, particularly with regard to what can be ruled out.

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1. Introduction

Forensic medicine typically poses questions as to the type or form of violence exerted in any given case.

One particular question in any instance of an apparent train suicide is whether there are findings that suggest that death or significant incapacitation by a third party had occurred prior to the body being overrun by the train [1]. Another, overlapping problem is that of differentiating a complex suicide, whereas a planned complex suicide connotates the simultaneous or combined application of different forms of violence, from an (initially unplanned) complex suicide with what may appear as more improvised sequential attempts of using a single method at a time [2,3].

PMCT (post mortem computed tomography) as method is also suggested for pre-autopsy screening or triage [4], particularly also for the head in context of the bone morphology in firearm injuries[1], and yet, with one exception[2], the proposition of specifications for related procedural PMCT improvements appears to remain untouched so far. Along the same route, current developments in high grade trauma screening such as mass disaster victim examinations also will benefit from an increased focus on PMCT performance in particular, in order to better inform the design of such an overall procedure[3].

The examiners thus may have to consider that clues indicative of mechanisms other than the assumed or apparent one may be present in their cases, and that their task may consist in identifying proper procedures to go about such clues[4].

This forensic case examined the suicide of a 52-year old man, in an Inner Swiss rural alpine canton, who ostensibly had first placed a wooden chair on the tracks, sat down, shot himself through the head with a pistol, before being hit by the train immediately after. A firearm injury to the head with subsequent high grade blunt trauma skull fragmentation due to a train impact produces shape details whose forensic discrimination requires a sufficiently high resolution. The technical question here is how theory for digitization and practical case results correlate, and what sensible conclusions for the triage of high grade trauma case work may result.

2. Method and material

2.1. Case report

In a rural alpine canton, a 52-year old man placed a wooden chair onto railway tracks, reportedly sat on it, then presumably shot himself through his head using a pistol, when the train hit and ran over him. It was night time, with the place poorly lit. According to first information about this case, the train driver allegedly had seen the man sitting on a chair right on the train track, the arm with pistol elevated and pistol directed to head, with a subsequent collapse of the body, consistent with a position right after a head shot, immediately before the train impact.

The examination of the body was performed by a board certified forensic pathologist, the death scene was also documented and examined by forensic scientists. Forensic test of the hands for gunshot residue (filter paper, rhodizonate test [16]) was negative while the examiners observed also covering of the hands with what appeared to be large amounts of both blood and dirt. The examination of the collision scene identified a pistol (SIG P210 pistol, caliber 7.65, by SIG, Neuhausen, SH, Switzerland), and a single case/shell, matching the pistol's caliber, was identified nearby. The weapon appeared to be severely damaged, and exhibited a hammer in a cocked position while the sleigh was jammed, magazine missing and the whole weapon contaminated with blood. The ownership of the weapon reportedly could be attributed to the man. The chair was broken. Close to where the pistol was found, one of the two rails exhibited blood drops with slightly jagged edges and a blood drop diameter range from $\sim$ 0.5 to 20 mm, in keeping with the assumption of a head shot with a victim's head wound elevated from the ground.

There was a highly fragmented head and skull, amounting to decapitation (see Fig. 1 A–C). Also, there was amputation of the left arm at the shoulder and both legs at the thighs, with numerous additional fractures. No apparent and definitive soft tissue defect consistent with a perforating gunshot injury was found on the remaining portions of the scalp (or remaining portion of the skin) as well as elsewhere on the body but due to the overall state of the scalp could not be excluded entirely. Time of death estimation based on body temperature and ambient temperature was consistent with the indication of the train driver that had reported seeing the man sitting on that chair, and the associated collision time.

No written suicide note was identified at the scene or at the victim's home. For further examination including identification and CT scanning, the body was admitted to our institute.

2.2. PMCT

Whole body scan: a dual source CT scanner (Somatom Definition Flash)[5] with a collimation of 0.6 mm, tube current of 120 kVp, dose modulation with an 400 mAs reference and a spiral pitch of 0.35 was used for the whole body scan (Fig. 1, reconstructed slice thickness 2,0 mm, pixel spacing 1.46 mm at a slice distance of 1.0 mm) (conforming to our standard protocol [17], with separate scan and reconstructions for thorax and abdomen, as well as separate reconstructions for the scan region covering the fragments of the skull). – *Side-by-side flat layout of the skull fragments:* an additional scan (Figs. 1G,H, 2A,B and 3A,B; pixel spacing 1.05 mm, slice distance 10 mm) with a 900 mAs reference was performed, capturing the skull bone fragments placed next to each other.

[1] Regarding firearm injuries to the head and PMCT, some studies issued a concise scope of the method capability [5], others explicitly mentioned several limitations of PMCT but not bone morphology [6,7], or they did not detail specific PMCT-related limitations but added autopsy findings [8–11]), while one study stated PMCT to be highly sensitive in identifying the main forensic items in gunshot victims [10].

[2] From [6]: "(..) example of the limitations of the postmortem MSCT method, the most important of which are imposed by the absolute resolution of the systems (..),"

[3] From [12]: "(..) Bones are well seen on CT and even if heavily burnt or even calcined, still readily recognizable." (...) "In only one case was there the suggestion of bone injury that might have been a mechanism of death other than the effects of fire, i.e. C6,7 dislocation. This finding was relayed to the pathologist prior to autopsy and lead to a detailed anatomical dissection of the deceased's neck that otherwise would not have been performed. (..) " – From [13]: "(..) the (..) authors suggested that (..) an external body description and osteological report of the remains could be conducted from 3D reconstructions (..)" – From [14]: (..) The imaging protocol needs to be tailored to the particular needs of the investigation and data handling capabilities. However, considering the hardware and software needs and the capability of all current CT scanners it should be possible to perform an optimal CT study in all instances (..) Reducing slice thickness whilst maintaining image quality (signal-to-noise ratio) requires higher X-ray exposure, increasing x-ray tube heating (tube-loading), which may be a problem for older generation CT scanners. (..) If tube-loading alerts prevent setting the required scan thickness, do not scan at lower resolution but consider: reducing individual scan lengths, increasing scan time, higher kV and lower mAs, apply "auto-mA", etc. in accordance with technical experience (..) Scanning the head and cervical spine separately also allows for a smaller FoV, increasing the spatial resolution.(..)

[4] From [15]: (..) "Forensic pathologists were stated to be ethically responsible to examine all human remains, regardless of size, preservation status and despite their specific challenges" (...). "Small fragments may have identifiable features, such as ridge detail, which can assist or progress positive identification" (..)

[5] The scanner setup used here is a dedicated post-mortem scanner. For heightened hygiene aspects in cases of clinical radiology scanner use, appropriate containers may have to be used.

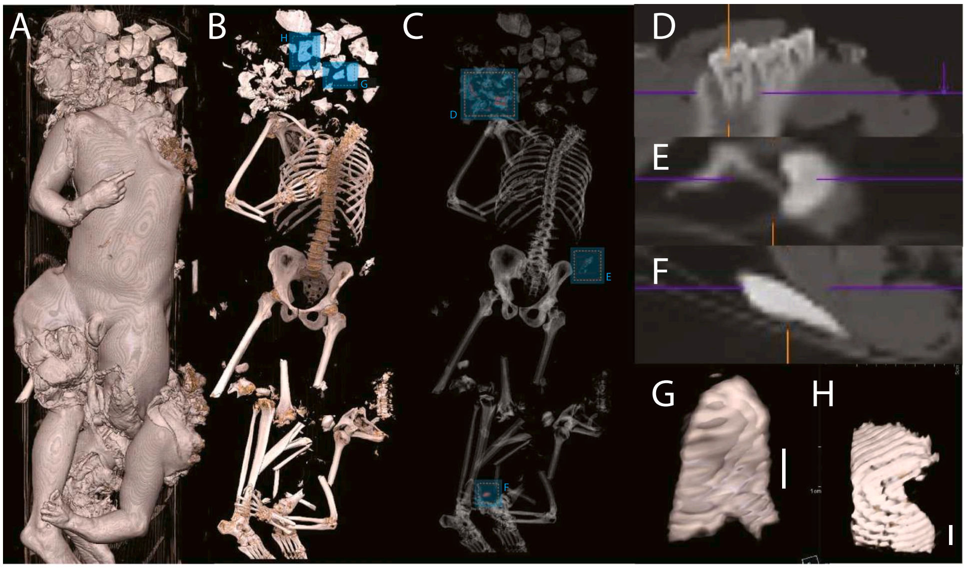

Fig. 1. PMCT reconstructions showing VRT at skin density (**A**), at bone density (**B**), and (**C**) at high CT density (*red*: >~ 2100 Hounsfield units). Location of images **D**–**H** relative to body marked in **B** and **C.** – No metal fragments were identified; details of dense materials (**D, E, F**) show these are teeth. – Two bone fragments at whole body PMCT resolution showed what appeared to be fracture margins consistent with the assumption of a pistol shot inflicted perforation or defect (fragment 1: **G**, fragment 2: **H**; details see Fig. 2 and 3). Bar (**G, H**) 1 cm.

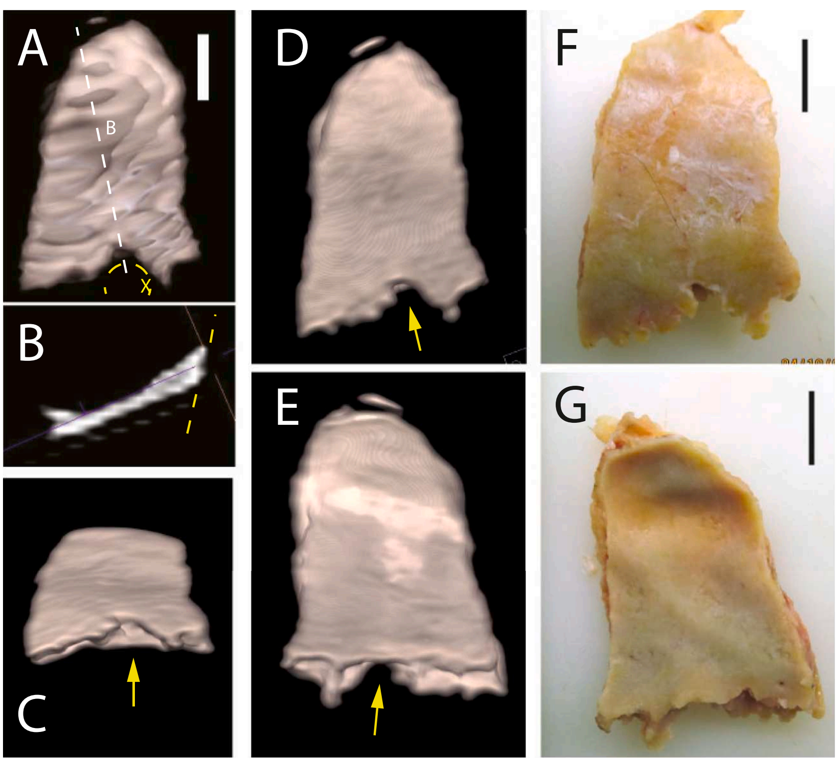

Fig. 2. Fragment 1 – On initial whole body PMCT (A), the imaging data of this bone fragment appeared to exhibit a semicircular defect (yellow dashed circle labelled *x*) that initially seemed possibly consistent with the assumption of a perforating pistol shot injury with outward beveling (**B**, yellow dashed line, reference to fragment of image **B** see white dashed line in **A**). More refined PMCTA reconstructions from same CT raw data (**C–E**) correlated better with the physical bone fragment margins whereas curvature on outer (**D, F**) (but not inner, **E** and **G**) compact table was that of a ruptured bone suture line. Ultimately, only the photographic appearance of the bone fragment contours allow to understand how the relatively low resolution of the CT images imply what appears to be a semicircular defect. Bar 10 mm.

– *Single fragment reconstructions:* From the bone fragment scan's raw data, more refined reconstructions (Figs. 2C–E and 3 E – J) were obtained for correlation (pixel spacing 0.14 mm, slice distance 0.15 mm). – *Thorax and abdomen:* Furthermore, the thoracic and abdominal organs were scanned (400 mAs reference, 0.4 mm spiral pitch, slice thickness of 1.0 mm and 1.07 mm pixel spacing). – *Reconstructions:* for this study, soft tissue (30) and bone kernel reconstructions (50) were used. – *Software:* standard CT reconstruction software (Siemens, Erlangen, Germany) was employed for axial image viewing, VRT (volume rendering technique) reconstructions and for MPR (multiplanar reconstructions).

3. Results

The case-specific forensic question was that of identifying consequences of a suspected gunshot-specific injuries to the head in this case with relatively high degree of traumatic fragmentation of the skull possibly attributable to a subsequent train collision. The whole body PMCT with separate reconstructions as well as both death scene and within-institute second external examination had not yielded any indication for a firearm injury to the neck, thorax, abdomen or the extremities and no projectile or foreign bodies suspicious of projectiles or their fragments.

Screening of the whole body PMCT identified two skull fragments

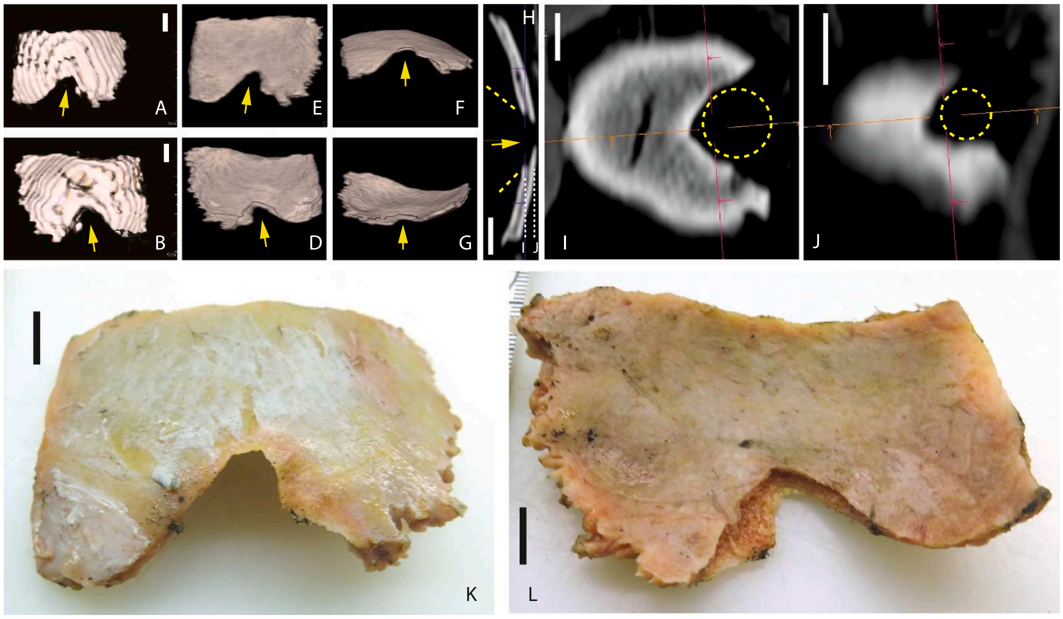

Fig. 3. Fragment 2 – This fragment exhibited a semicircular defect visible on initial whole body PMCT (**A, B**, yellow arrow) that appeared to be consistent with a gunshot injury. Refined PMCT reconstructions (VRT: **E–G**; MPR: **H–J**) correlated well with the macroscopic (photos: **K, L**) appearance whereas a slightly irregularly shaped round semi-circular defect of approximately 8 to 12 mm diameter of the outer cortical bone table (**H** and **J**, yellow dashed circle) contained a beveled (yellow dashed lines, H) defect shape towards a larger defect of the inner cortical bone table (**H** and **I**, yellow dashed circle) with several dark gray discolorations, also on the assumed gunshot injury circumference, consistent with gunshot residue. Bar 10 mm.

that came into closer consideration for possible perforating pistol shot injuries, where we clearly focused on typical rather than atypical morphology [18]. They were labeled fragment 1 (Fig. 2) and 2 (Fig. 3).

Fragment 1 (Fig. 2) measured $40 \times 26 \times 3.5$ mm. It contained a semi-circular indent on one edge that was apparent already on whole body PMCT. It appeared to be an at least halfway plausible candidate for a "typical" perforating skull defect[6], roughly consistent with a 7.65 mm caliber pistol[7]. Subsequently higher resolution data analysis and macroscopic validation showed this finding to be a ruptured bone suture line.

Fragment 2 (Fig. 3) measured $70 \times 435 \times 47$ mm. It exhibited a semi-circular defect, whereas the defects of the outer ($\sim 8 - 12$ mm) and inner ($\sim 15 - 20$ mm)) cortical bone table of this skull fragment provided a constellation typical for a gunshot entry wound (beveled bone edges: see yellow dashed lines in Fig. 3 H) [18].

In the context of the extensive blunt trauma due to the body being run over by the train, the lungs exhibited multiple pneuomatoceles. The lower lobe of the right lung appeared to contain a nodular patchy ground-glass pattern, consistent with aspiration of gastric content and subsequent bronchiolitis [19–21].

Due to the information brought about by the police investigation and medicolegal examination in conjunction, no evidence for homicidal involvement was found. This predisclosed further detailed examination of a range of technical aspects. Tests or examinations that would have been possible but were not found necessary and thus no requested included full autopsy, including histology and toxicology, anthropological study and assembly of bone fragments particularly of the skull, evaluation of all DNA evidence, and a more refined examination for gunshot residue on the samples taken. The information and all findings were found to be consistent with (albeit not proof of) a complex suicide with pistol shot to the head and train collision. While a different manner of death could not be ruled out with certainty, no actual evidence for homicidal death was found. The possibility of accidental death was not pursued further in that the Swiss Penal Code commands that, when no evidence of third party involvement is found, the district attorney releases the body without autopsy.

4. Discussion

This case-report describes findings and circumstances that were interpreted as consistent with assumption of a complex suicide of a 52-year old man, combining a pistol head shot with being run over by a train immediately afterwards, while no suicide note was found. With that, it appeared that two suicide methods that are frequent in Switzerland [22] were employed, resulting in a very rare combination. To the best of our knowledge, this is the first published forensic case that details what appears to be the combination of a train and head shot suicide in a planned complex constellation. In other situations, planned complex suicides combined electrocution with hanging [2], firearm injury to the head and hanging [23,24], firearm injury to the head in a driver of a car that apparently caused a head-on-collision with a truck [25], firearm injury to the head combined with fire in vehicle or combined with home fire [24], hanging and fire at home or work place [24] or stabbing to the chest, fall from great height and drowning [24].

Absence of rhodizonate-positive filter paper stain of the man's hands

[6] From [18], page 100: "When a bullet perforates bone, it bevels out the bone in the direction in which it is traveling (...). The entrance has a round to oval, sharp-edged, punched-out appearance (...). The opposite surface of the bone, i. e., the exit side, is excavated in a cone-like manner (...). This difference in appearance of entrance and exit wounds is best seen in the flat bone of skull. As the bullet enters, it creates a round to oval sharp-edged hole in the outer table of the skull, with a large, beveled-out hole on the inner table. When the bullet exits the cranial cavity, the inner table is the entrance surface and the outer table the exit surface.Chips of bone can flake off the edge of an entrance hole."

[7] While the shape variation of firearm related injuries may be regarded as sufficiently wide to stay clear of overly specific expectations, fracture morphology still may allow for differentiation: take, for example, a sharply demarcated rectangular slit-like fracture in a skull e.g. measuring 1 x 45 mm. Such a lesion may be seen as "typical" for a sharp blade, but not at all as "typical" for a 7.65 mm caliber firearm ammunition. It is in that context where we approached morphology by searching "plausible candidates" or lesions "consistent with" the assumption of at least a "typical" gunshot injury to the head, in the overall context of this case.

in this case could be interpreted as false-negative [26] given the overall situation, which also included the presence of a shell matching the ammunition, a cocked hammer of the pistol and attribution of ownership.

Absence of a clearly identifiable head shot injury with only plausible bone fragment shapes does not rule out a pistol shot in this case: the search for gunshot injuries in skeletal remains or in otherwise highly fragmented or injured soft tissues and organs for retained projectiles is not always and necessarily successful. In one study examining fatal gunshot wounds, 5% of the cases did not contain a bone lesion or an intracorporeal projectile [27].

Absence of clearly identifiable blood aspiration to the lungs in this instance does not preclude a firearm injury to the head seconds before the train caused the severe head injuries [20]. Victims of planned complex suicides tend to be male and of an average age over 50 years [24].

Absence of suicide note does not rule out suicide; suicide notes were only found in eight of fourteen planned complex suicides [24].

A particular technical aspect to consider particularly in relatively high fragmentation trauma, such as this collision of a person with a train, or after a plane crash, is that the examination may have to carefully inspect all bone edges, and specifically check also for rounded or oval margin portions, or slit-like bone injuries, possibly indicative of e.g. sharp force or gunshot trauma, unless the circumstances otherwise rule out such other forms of trauma. This may be impossible particularly on basis of PMCT data, both if bone fragments are mingled and too close together, causing overlap [28], or if the data is not sufficiently highly resolved.

One lesson to be learned was that it may be crucial in particular cases to provide a sorted arrangement of the remains for better PMCT scanning at once, and to retain raw data for more detailed reconstruction until the examination of the whole case is finished. Not always will it be possible to perform a second scan as in this instance.

4.1. PMCT layout of fragments

A careful arrangement of single bone fragments in the CT-scanner should be ensured, following general principles of separation and then segmentation [29]. Only then may the PMCT data allow for a meticulous bone fragment edge inspection. From a viewpoint of disaster victim identification, anatomically disjunct specimen may have to be collected, labeled, packed and further analyzed individually anyway [15].

4.2. PMCT data resolution

Resolution of PMCT in this case did not provide the necessary level of detail, particularly at first. So a second scan had to be performed whereas dedicated reconstructed data achieved an almost isotropic (pixel distance 0.14 mm x slice thickness 0.15 mm) resolution, but bone morphology details (Figs. 2 and 3) with regard to the forensic question in this case were still captured marginally at best.

Generally, digitizing analog shapes with focus on quality may require that a feature or structure be captured with at least 24 digital elements; as example, a 1 mm sized feature is recommended to be scanned with a resolution of at least ~1/24 mm, i.e., ~615 dpi, for sufficiently high quality. Conversely, ~15 digital elements per mm (~385 dpi) may be required for medium quality and with ~11 digital elements per mm (~277 dpi) a relatively low quality [30] may be achieved. In this instance, digitization of a perforating injury of an arbitrarily chosen 10 mm diameter may just barely conform to these requirements for high quality data with a voxel size anywhere between 0.4 (high quality) to 0.9 (low quality) mm. If one however does not regard the whole defect related to a gunshot skull penetration as the single feature to be digitized but its firearm-typical lesion substructures, such as fracture margin details [31,32], then structures of 1-2 mm may have to be digitized properly. This then may require a voxel size of 0.04 to 0.18 mm for a satisfying injury specification.

One particular suggested device to use for whole-body screening was a custom-built micro-CT, whereas an isotropic resolution of around 100μ to scan a typical whole-body volume of e.g. 55 x 55 x 187 cm may easily take up storage of around 1 Terabyte, whereas with a resolution of 25μ one may even exceed 65 Petabyte; such a scan may take many hours to a few days, and thus also require particular thermal and mechanical stabilization. Because of an apparent lack of feasibility of devices with such high resolution, practical case work usually has to cope with far lower resolution. There, other factors such as convenience, cost [33] of replacing X-ray tubes and storage space are factored in [17,34,35], resulting in overall strategies with certain restrictions.

4.3. Interpretation in cases of high degree of fragmentation

The interpretation of fracture and fragmentation causes in cases with a high degree of fragmentation will have to be worded cautiously. Leading up to that, however, any practical differentiation should be attempted to the degree possible. There, it appears that even in instances of high degrees of bone fragmentation, differentiation between hammerstone percussion, carnivore gnawing, weathering, trampling or thermal fragmentation such as burning has been attempted [36–40]. To justify a meticulous study of fragments, one also has to keep in mind that in a study collective with known fractures before cremation, these same fractures could be identified after cremation in almost a third of the cases [41].

With fragments attributable to a single case, physical assembly may be attempted in order to reconstruct a fracture pattern [42]. However, even automated virtual assembly of bone fragments will also require sufficiently high resolution to allow for adequate fracture edge shape encoding [43,44].

4.4. Conclusion

Further research is necessary with focus on optimal data quality. There, significantly increased resolution, while at the same time, a maximal CT dose and maximal noise reduction may have to be targeted, even – if not particularly – for routine applications [10,45]. In terms of interpretation findings with regard to manner of death, a particularly high degree of fragmentation of a body may make the identification of potentially present smaller injuries, even if they may be expected to be specific, so hard or impossible, that they quite possibly may not be ruled out with certainty [46], but a statement can only be given after a detailed examination of all fragments or body parts.

At any rate, pushing technology beyond its limitations, depending on jurisdiction, however, may not be necessary at least seeing from that end. Swiss Penal Code does not require the investigative authorities – including the medico-legal examination – to present a unanimous manner of death, or to exclude any type of injury, as long as there is no (positive) indication, hint or evidence of possible homicidal death.

Declaration of Competing Interest

The authors declare that they have no competing interests.

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